Validation of an Integrated System for a Hydrogen-Fueled Power Park

Todd Carlson (Primary Contact), Dave Guro, Greg Keenan
Air Products and Chemicals, Inc.
7201 Hamilton Blvd, Mail Code A5315
Allentown, PA 18195-1501
Phone: (610) 481-4217; Fax: (610) 481-3614; E-mail: carlsote@apci.com

DOE Technology Development Manager: Sigmund Gronich
Phone: (202) 586-1623; Fax: (202) 586-9811; E-mail: Sigmund.Gronich@ee.doe.gov

Objectives

- Determine the optimal natural gas to proton exchange membrane (PEM) power system
  - Central reformer or local reformers
  - Central PEM or local PEM
  - Waste heat utilization
  - Operating mode
- Determine the ideal site for a power park
  - Total peak power
  - Power profile
  - Commercial or industrial
  - Utilization
- Optimize the system for lowest total power price
- Demonstrate a prototype natural gas to PEM power park at a suitable site

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- E. Durability
- F. Heat Utilization
- G. Power Electronics
- H Startup Time

Approach

- Investigate and estimate the cost for each system configuration
- Determine the optimal (lowest cost of power) system configuration
- Provide the best cost of power today and in the future
- Determine building types that are amenable
- Determine the optimal operating mode (baseload, peakshave, backup, island)
- Investigate fuel cell capabilities today vs. optimal operating requirements and DOE targets

Accomplishments

- Modeled the cost of power as a function of fuel cost, efficiency, maintenance, fuel cell and reformer costs, return on investment, and overhead
- Determined the required fuel cost, efficiency, and capital costs to provide 10% return on investment at $0.10/kWh cost of power
- Determined the amenable building types
- Determined the unit costs of hot water piping, hydrogen piping, and electrical wiring
- Estimated the impact of waste heat utilization on the cost of power
- Examined current state-of-the-art reformer, purification, power conditioning, and fuel cell systems
- Studied various distributed generation projects to identify the factors that contributed to the decision to install distributed generation

Future Directions

- Hydrogen energy stations (fueling and power generation concurrently)
- Other system cycles that are more efficient

Introduction

The goal of this project is to develop an optimized power generation system with natural gas as the fuel and PEM fuel cells providing the conversion to electricity. The first step of this project was to identify all possible processes that could be used to produce power from natural gas. Construction and capital costs were then collected from all available vendors of reformers, purification, and fuel cells. A cost of power model was built to provide rapid calculations while changing inputs. The selection of the optimal process was then completed based on the cost of power.

The next step involved a reverse calculation to determine what fuel cost, utilization, capital costs, and efficiency were required to achieve a target electricity cost of $0.10/kWh. These answers determined the target size, operating mode, costs, and efficiencies for the system to meet DOE targets. The optimal system did not meet the DOE targets, so we continue to look into hybrid systems, such as the Hydrogen Energy Station (joint fueling and power production).

Approach

Each process was modeled using ASPEN Plus (modeling software) to determine system efficiency and potential waste heat. The construction costs were estimated by our construction estimating group using Penn State as the site with three buildings located 200 yards (each) away from a central location. The capital cost of reformers, purification systems, and fuel cells were determined by obtaining quotations from all identified manufacturers. The cost of power model was developed from our standard cost of gas model. Building power profiles were provided by Joe Huang, Lawrence Livermore National Laboratory (LLNL).

Results

There are a number of improvements that are required to achieve $0.10/kWh power cost. These include:

- 25% increase in overall efficiency
- 4000% increase in fuel cell life
- 500% increase in power output
- 95% reduction in cost of PEM fuel cell and 75% reduction in cost of reformer system

The most effective use of PEM power both in terms of power cost and environmental impact would be in a baseload power application.

Combined heat and power has a minor effect on the cost of power, as the reformers already utilize the majority of the waste heat. The remaining waste heat is low grade and is most likely only amenable to supplementing hot water requirements.

Conclusions

- Today's cost of power from natural gas fueled PEM fuel cells is $0.45/kWh.
- Pressurized steam methane reforming with pressure swing adsorption (PSA) purification is the optimal system.
- Requirements to reduce cost to $0.10/kWh include:
  - 40% total efficiency (31% best today)
  - $3,300/kW capital cost ($14,000/kW today)
  - 15 year life or 131,400 hrs (1,000 hrs today)
  - $3.37/MMBTU natural gas price ($5.65/ MMBTU at smaller sizes)
- Size of the system needs to be above 800 kW to achieve industrial natural gas rates.
- Hydrogen energy station or other complex cycles could provide better utilization or efficiencies.

References

1. Joe Huang (LLNL) - building power profiles
2. Vendors - Reformer, PSA, metal membrane, and fuel cell costs and performance data.

FY 2003 Publications/Presentations

1. Poster Session at 2003 Annual Program Review and Peer Evaluation